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(54) RAFFINEUR DE COPEAUX DE BOIS A DISQUE ROTATIF

(54) ROTATING DISC WOOD CHIP REFINER

(57)

A rotating disc wood chip refiner apparatus with an improved helical ribbon screw feeder comprising radially positioned right-hand and left-hand helical ribbon bars, each bar having a corresponding feeder outlet ring having a grid of skewed axial slots having a multiplicity of volumes, forming a continuous series of tuned resonant cavities. The slots in a feeder outlet ring corresponding to a right-hand helical ribbon bar are axially and uniformly skewed backwards (i.e. counter-clockwise) for a right-hand screw; and the slots in a feeder outlet ring corresponding to a left-hand helical ribbon bar are axially and uniformly skewed forwards (i.e. clockwise) for a left-hand screw, so that the helical ribbon bar/skewed axial slot-crossings are nearly parallel. A wave packet of forward travelling waves produced by the additional continuous series of tuned resonant cavities at the helical ribbon bar/skewed axial slot-crossings of the improved helical ribbon screw feeder described in this invention, can achieve a Bjerknes resonator action, with synergistic advantages to the usual continuous series of tuned resonant cavities at the refiner plate bar-crossings, at a frequency of half or integral multiples of the frequency of the wave packet of forward travelling waves, which can be adjusted to a family of resonant harmonic vibrations ranging from about 800 hertz to about 30,000 hertz, and provides a longer refining residence time, and achieves increased surface properties for a stronger pulp and paper sheet formation.

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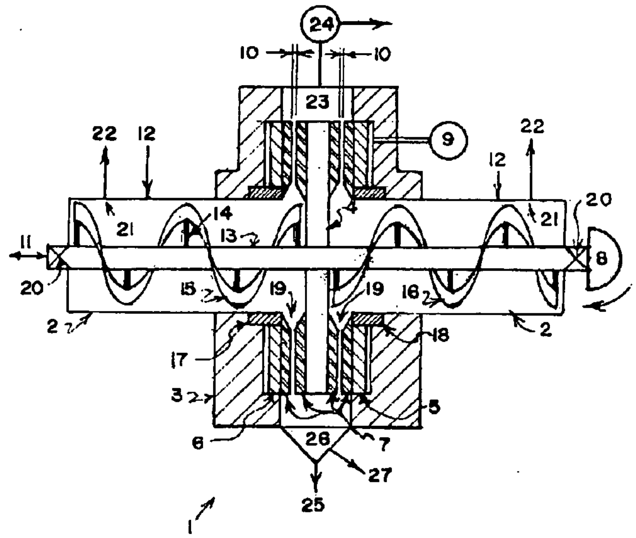

(57) A rotating disc wood chip refiner apparatus with an improved helical ribbon screw feeder comprising radially positioned right-hand and left-hand helical ribbon bars, each bar having a corresponding feeder outlet ring having a grid of skewed axial slots having a multiplicity of volumes, forming a continuous series of tuned resonant cavities. The slots in a feeder outlet ring corresponding to a right-hand helical ribbon bar are axially and uniformly skewed backwards (i.e. counter-clockwise) for a right-hand screw; and the slots in a feeder outlet ring corresponding to a left-hand helical ribbon bar are axially and uniformly skewed forwards (i.e. clockwise) for a left-hand screw, so that the helical ribbon bar/skewed axial slot-crossings are nearly parallel. A wave packet of forward travelling waves produced by the additional continuous series of tuned resonant cavities at the helical ribbon bar/skewed axial slot-crossings of the improved helical ribbon screw feeder described in this invention, can achieve a Bjerknes resonator action, with synergistic advantages to the usual continuous series of tuned resonant cavities at the refiner plate bar-crossings, at a frequency of half or integral multiples of the frequency of the wave packet of forward travelling waves, which can be adjusted to a family of resonant harmonic vibrations ranging from about 800 hertz to about 30,000 hertz, and provides a longer refining residence time, and achieves increased surface properties for a stronger pulp and paper sheet formation.

ABSTRACT

A rotating disc wood chip refiner apparatus with an improved helical ribbon screw feeder comprising radially positioned right-hand and left-hand helical ribbon bars, each bar having a corresponding feeder outlet ring having a grid of skewed axial slots having a multiplicity of volumes, forming a continuous series of tuned resonant cavities. The slots in a feeder outlet ring corresponding to a right-hand helical ribbon bar are axially and uniformly skewed backwards (i.e. counter-clockwise) for a right-hand screw; and the slots in a feeder outlet ring corresponding to a left-hand helical ribbon bar are axially and uniformly skewed forwards (i.e. clockwise) for a left-hand screw, so that the helical ribbon bar/skewed axial slot-crossings are nearly parallel. A wave packet of forward travelling waves produced by the additional continuous series of tuned resonant cavities at the helical ribbon bar/skewed axial slot-crossings of the improved helical ribbon screw feeder described in this invention, can achieve a Bjerknes resonator action, with synergistic advantages to the usual continuous series of tuned resonant cavities at the refiner plate bar-crossings, at a frequency of half or integral multiples of the frequency of the wave packet of forward travelling waves, which can be adjusted to a family of resonant harmonic vibrations ranging from about 800 hertz to about 30,000 hertz, and provides a longer refining residence time, and achieves increased surface properties for a stronger pulp and paper sheet formation.

BRIEF SUMMARY OF THE INVENTION

This invention relates to rotating disc wood chip refiner apparatus, which is useful for the separation and defibrillation of wood chips into unravelled single long-developed fibers. The refiner has an improved helical ribbon screw feeder to provide a longer refining residence time, and supplies an additional wood separation zone and an additional bar-crossing flow regime, just before the usual wood separation zone and the usual bar-crossing flow regime between the refiner plates. This is conducive to higher pulp quality to achieve better pulp and paper sheet formation. The refiner and the improved feeder utilize a tuned resonating cavity model of wood refining with a low fluid-dynamic drag helical ribbon bar profile, and a low fluid-dynamic drag skewed axial bar profile, and a pressure-recovery skewed axial slot profile to minimize energy input.

BACKGROUND ON A ROTATING DISC WOOD CHIP REFINER

Usual rotating disc wood chip refiner apparatus can utilize a 12,000 hp (9,000 KW) rotating means to refine a nominal capacity of 200 tonnes per day of oven-dry wood chips, and may generate up to 40,000 pounds (18,000 kg) per hour of steam production by heat recovery for mill use. The usual forward flow of steam and refined fibers moving thru the refiner plates is controlled by a pressure-regulating valve, which adjusts the recovery steam production rate to the mill, according to the overall refining operations. A common-pressure hydraulic system maintains the operating refiner plate gap in relation to the measured degrees of the refining process.

A rotating disc wood chip refiner may utilize two or three circular discs, sometimes one axially movable stationary disc and one axially fixed-position rotating disc, sometimes two counter-rotating discs with one axially movable rotating disc and one axially fixed-position rotating disc, and other times, one axially movable stationary disc on each side of axially fixed-position rotating disc.

A rotating disc wood chip refiner apparatus may utilize one face or two faces of the rotating disc, which is mounted usually on the helical ribbon screw feeder/axial fixed-position rotating disc shaft:

a) a single direction helical ribbon screw feeder, either a right-hand screw or a left-hand screw, may feed wood chips into the "eye" of one face of the axial fixed-position rotating disc, at the entrance into the refiner plate gap between the axial fixed-position rotating disc and the axial movable stationary disc.

b) a single direction and separated helical ribbon screw feeder, with a right-hand screw on one end of the helical ribbon screw feeder/axial fixed-position rotating disc shaft, and a left-hand screw on the opposite end of the helical ribbon screw feeder/axial fixed-position rotating disc shaft, may feed wood chips into the "eye" of both faces of the axial fixed-position rotating disc, at the entrance into the refiner plate gaps between both faces of the axial fixed-position rotating disc and the two opposed axial movable stationary discs.

c) a single direction helical ribbon screw feeder, with either a right-hand screw or a left-hand screw on the helical ribbon screw feeder/axial fixed-position rotating disc shaft, may feed wood chips into the "eye" of two opposing faces of two counter-rotating discs, at the entrance into the refiner plate gap between the axial fixed-position rotating disc and the axial movable rotating disc.

A rotating disc wood chip refiner apparatus utilizes a helical ribbon screw feeder with two functions:

a) first, to carry the forward flow of wood chips towards the "eye" of a face of a rotating disc

b) second, to allow the backward flow of exhaust steam, generated by the wood refining process, to pass thru the annular space between the helical ribbon bar and the feeder/rotating disc shaft, and this exhaust steam is useful to pre-heat wood chips and for mill use.

Atack (1) described wood chip separation and defibrillation in a rotating disc wood chip refiner as a combination of beating and shearing actions at the bar-crossing interface, and reported classic studies of the four stages of wood refining, as match sticks, fiber bundles, single fibers, and unravelled, brushed ends on some fibers. Hoerner (2) published fluid-dynamic drag coefficients for various profiles of bars and slots. Adkins (3) discussed the advantages of a slot/vortex fence, and listed some pressure-recovery data for various slot profiles. Rockwell (4) studied the self-sustaining oscillations of flow past cavities. Forgacs (5) characterized the properties of mechanical pulps. Colby (6) provided an engineering review of tuned resonant cavities. Lin (7) reportedsome theoretical concepts of oscillating flows. Archibald (8) studied the vibratory motions of a string, which can be related to a single wood fiber. Beranek (9) discusses various practical examples of tuned resonant cavities. May (10) obtained test results of backward and forward flows of steam in refiners. The Wood Handbook (11) lists properties of woods used to calculate the wave velocities. Prandtl (12) translated and summarized Bjerknes's work (13) on the advantages of forward travelling waves in fliuids, and Drazin (17) describes parametric resonance. Gymarthy (14) reported condensation shock effects in steam flow. Leith (15) described steam flow instabilities and erosion. Leith (16) developed a math model for a tuned resonant cavity model of wood refining. Merchant (18) reported an orthogonal cutting model which appears related to the usual beating and shearing action at bar-crossings in a refiner.

ROTATING DISC WOOD CHIP REFINER

with an IMPROVED HELICAL RIBBON SCREW FEEDER

This invention relates to rotating disc wood chip refiner apparatus which is useful for the separation and defibrillation of wood chips into unravelled single long-developed fibers. The refiner has an improved helical ribbon screw feeder to provide a longer refining residence time, and supplies an additional wood separation zone and an additional bar-crossing flow regime, just before the usual wood separation zone and the usual bar-crossing flow regime between the refiner plates. This is conducive to higher pulp quality to achieve better pulp and paper sheet formation. The refiner and the improved feeder utilize a tuned resonating cavity model of wood refining with a low fluid-dynamic drag helical ribbon bar profile, and a low fluid-dynamic drag skewed axial bar profile, and a pressure-recovery skewed axial slot profile to minimize energy input and to improve loadability of the refiner apparatus. Improved loadability results when the nominal rotating means energy input can provide a higher pulp quality at the nominal capacity of wood chips. Various additional techniques to the usual helical ribbon screw feeder in a rotating disc wood chip refiner involve the addition of a continuous series of tuned resonant cavities at the helical ribbon screw feeder outlet which provide forward travelling waves with a Bjerknes resonator action with synergistic advantages to the usual continuous series of tuned resonant cavities at the refiner plate bar-crossings.

The important design criteria for a rotating disc wood chip refiner apparatus with an improved helical ribbon screw feeder with a tuned resonating cavity model of wood refining, utilizes a family of resonant harmonic vibrations, which totalize three self-sustaining oscillations of flow past a cavity:

a) fluid-dynamic oscillations mainly due to the helical ribbon bar/skewed axial slot-crossings, provide the required pulsating cavitation flow regime of pressure/vacuum cycles with a frequency range of about 800 hertz to about 30,000 hertz

b)fluid-resonant oscillations of the wood chip in the slot cavity, permit resonance for wood chips 10 mm (3/8 inch) cubes down to single wood fibers 0.05 mm (0.002 inch) diameter by 3 mm (1/8 inch) long, with a frequency response range from about 800 hertz to about 30,000 hertz, when filled with wood, water, steam or air contents

c) fluid-elastic oscillations mainly due to the helical ribbon bar/skewed axial slot-edge profiles, provide a coupling of elastic, inertia and damping properties which permit defibrillation of a single wood fiber tethered to a wood chip, by longitudinal shear failure between the longitudinal-oriented S_2 layer and the transverse-oriented S_1 layer/-middle lamella layers. Unravelling of a separated hollow wood fiber occurs along its spiral seam of the longitudinal-oriented S_2 layer, with broomed or brushed fiber ends.

A rotating disc wood chip refiner apparatus with an improved helical ribbon screw feeder comprising radially positioned right-hand and left-hand helical ribbon bars, each bar having a corresponding feëder outlet ring having a grid of skewed axial slots having a multiplicity of volumes, forming a continuous series of tuned resonant cavities. The slots in the feeder outlet ring corresponding to a right-hand helical ribbon bar are axially and uniformly skewed backwards (i.e. counter-clockwise) for a right-hand screw; and the slots in a feeder outlet ring corresponding to a left-hand helical ribbon bar are axially and uniformly skewed forwards (i.e. clockwise) for a left-hand screw, so that the helical ribbon bar/skewed axial slot-crossings are nearly parallel.

A wave packet of forward travelling waves produced by the additional continuous series of tuned resonant cavities at the helical ribbon bar/skewed axial slot-crossings of the improved helical ribbon srew feeder described in this invention, can achieve a Bjerknes resonator action, with synergistic advantages to the usual continuous series of tuned resonant cavities at the refiner plate bar-crossings, at a frequency of half or integral multiples of the frequency of the wave packet of forward travelling waves, which can be adjusted to a family of resonant harmonic vibrations ranging from about 800 hertz to about 30,000 hertz, and provides a longer refining residence time, and achieves increased surface properties for a stronger paper sheet.

This invention has skewed axial slots in the feeder outlet ring, as viewed from the rotating means end, and uniformly skewed from the helical ribbon screw feeder/rotating disc shaft axis, with an angle ranging from zero to 45 degrees counter-clockwise for a right-hand screw, and with an angle ranging from zero to 45 degrees clockwise for a left-hand screw, so that the helical ribbon bar/skewed axial slot-crossings are nearly parallel, to suit helical ribbon screws with a pitch to diameter ratio of 0.2 to 1.5, and to suit 1 to 4 helical ribbon bars located equally spaced radially on one helical ribbon screw feeder/ rotating disc shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

Sheet 1, FIG. 1 a diagrammatic side elevation, partly in section, of a rotating disc wood-chip refiner with an improved helical ribbon screw feeder

Sheet 2, FIG. 2 a plan of the orientations of the skewed axial slots on the right-hand screw/feeder outlet ring, and the left-hand screw/feeder outlet ring

FIG. 3 an end elevation, partly in section, of the right-hand screw, as located on the feeder/ rotating disc shaft

Sheet 3, FIG. 4 a cross-section of a square sharp-edged helical ribbon bar profile

FIG. 5 a cross-section of a square sharp-edged skewed axial bar profile, and a square sharp-cornered skewed axial slot profile

Sheet 4, FIG. 6 a cross-section of a low fluid-dynamic drag helical ribbon bar profile

FIG. 7 a cross-section of a low fluid-dynamic drag skewed axial bar profile, and a pressure-recovery skewed axial slot profile

Sheet 5, FIG. 8 a graph which indicates the effective use of a steam pressure/temperature pre-treatment of various softwoods and hardwoods

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a diagrammatic side elevation, partly in section, of a rotating disc wood chip refiner 1, and an improved helical ribbon screw feeder 2, with machine frame 3, three parallel discs 4,5,6 having facing surfaces for refiner plates 7, are mounted concentrically on frame 3. Usually rotating means 8 rotates disc 4 and the helical ribbon screw shaft 13, while discs 5 and 6 are stationary. Rotating disc 4 is in relative counter-movement to stationary discs 5 and 6. A common pressure hydraulic system 9 provides an adjustment for the refiner plate gap 10 and the disc thrust 11, to suit various refining operations with a variety of softwoods, hardwoods and eucalyptus species. Wood chips 12 are moved by the improved helical ribbon screw feeder 2, which has a helical ribbon screw/rotating disc shaft 13, with support lugs 14, holding the right-hand screw 15 and the left-hand screw 16. Wood chips 12 move thru the right-hand screw 15/feeder outlet ring 17, and the left-hand screw 16/ feeder outlet ring 18, and simultaneously enter the two "eyes" 19 of the refiner 1, and into the refiner plate gap 10, between the refiner plates 7. Bearings 20 carry the helical ribbon screw/rotating disc shaft 13 and the disc thrust 11. Backflow steam 21 exits at 22. Forward flow steam 23 leaves the refiner 1 thru the pressure-regulating valve 24, and refined wood fibers 25 leave at exit 26. Drain 27 is for maintenance

FIG. 2 is a plan of the orientations of the skewed axial slots 28 on the right-hand screw 15/feeder outlet ring 17, which may vary with an angle A from zero to 45 degrees counter-clockwise and on the left-hand screw 16/feeder outlet ring 18 which may vary with an angle B from zero to 45 degrees clockwise, looking from the rotating means 8 end of the feeder/rotating disc shaft 13.

FIG. 3 is an end elevation, partly in section, of the right-hand screw 15, with reference to helical ribbon bar profiles 29 and 32, located on the feeder/rotating disc shaft 13 by supporting lugs 14, bearings 20, and the feeder outlet ring 17, with reference to the skewed axial bar profiles 30 and 33, and to the skewed axial slot profiles 31 and 34.

FIG. 4 is a cross-section of a square sharp-edged helical ribbon bar profile 29, each with a top surface 29b, a leading edge 29a at the edge of the top surface 29b in the direction of the relative counter-movement or rotation of the helical ribbon bars 15/16 in the feeder outlet rings 17/18, and the two vertical side surfaces 29c.

FIG. 5 is a cross-section of a square sharp-edged skewed axial bar profile 30, each having a top surface 30b, a leading edge 30a at the edge of the top surface 30b in the direction opposite to the relative counter-movement or rotation of the helical ribbon bars 15/16 in the feeder outlet rings 17/18, and the two vertical side surfaces 30c; and a cross-section of a square sharp-cornered skewed axial slot profile 31, having a horizontal bottom surface 31a.

FIG. 6 is a cross-section of a low fluid-dynamic drag helical ribbon bar profile 32, where the helical ribbon bar profile generally indicated at 32, includes helical ribbon bars 32a, each bar 32a having a leading edge 32b, a substantially horizontal top surface 32c, and two substantially vertical side surfaces 32d. Leading edge 32b is the edge of the top surface 32c in the direction of the relative counter-movement or rotation of the helical ribbon bar 15/16 in the feeder outlet ring 17/18. Leading edge 32b of each bar 32a ia preferably rounded, such as, for example, with a rounding radius of about 0.4 mm (0.015 inch). Top surface 32c is preferably sloped downwards at an angle C towards the leading edge 32b. The angle C of the top surface 32c is small, and preferably about 6 degrees. Side surfaces 32d are preferably sloped at an angle D from the vertical such that each bar 32a is tapered down towards its top surfae 32c. The angle D of each vertical side 32d is small and preferably about 6 degrees.

FIG. 7 is a cross-section of a low fluid-dynamic drag skewed axial bar 33, where the skewed axial bar profile 33 generally indicated at 33, includes skewed axial bar 33a, each bar 33a having a leading edge 33b, a substantially horizontal top surface 33c, and two substantially vertical side surfaces 33d. Leading edge 33b is the edge of the top surface 33c in the direction opposite to the relative counter-movement or rotation of helical ribbon bars 15/16 in the feeder outlet rings 17/18. Leading edge 33b of each bar 33a is preferably rounded, such as, for example, with a rounding radius of about 0.4 mm (0.015 inch). Top surface 33c is preferably sloped downwards at an angle E towards the leading edge 33b. The angle E of the top surface 33c is small, and preferably about 6 degrees. Side surfaces 33d are preferably sloped at an angle F from the vertical such that each bar 33a is tapered down towards its top surface 33c. The angle F of each side surface 33d is small, and preferably about 6 degrees.
Also, FIG, 7 is a cross-section of a skewed axial pressure-recovery slot profile 34, includes skewed axial slots 34a, each slot 34a having a substantially horizontal bottom surface 34b. Bottom surface 34b is preferably sloped downwards from the horizontal at an angle G in the direction opposite to the relative counter-movement or rotation of the helical ribbon bars 15/16 in the feeder outlet rings 17/18. The angle G of the bottom surface 34b is preferably about 25 degrees. Generally, the angles E,F, and G should be such that the fluid-dynamic drag energy required for counter-movement or rotation will be reduced.

The preferred values of angles E, F, and G given above will reduce the fluid-dynamic drag energy by about 50% of the energy required for the square sharp-edged helical radial bar profile, and for the square sharp-edged skewed axial bar profile, and for the square sharp-cornered skewed slot profile.

FIG. 8 is a graph which indicates the effective use of a steam pressure/temperature pre-treatment of softwood and hardwood chips to accelerate water penetration into the hollow wood fibers to soften the lignin, and appears to indicate a common shear strength/ cutting force baseline.

PARAMETRIC RESONANCE

Prandtl (12) and Bjerknes (13) described the advantages of forward travelling waves in fluid flow, and the theoretical concepts of Bjerknes resonator action. Drazin (17) developed parametric resonance which involves targeted forced oscillations in forward travelling waves that can enhance the free oscillations in a basic periodic flow, at a frequency of half or integral multiples of the frequency of the forced oscillations.

In this invention, the wave packet of travelling waves produced by the additional continuous series of tuned resonant cavities at the helical ribbon bar/skewed axial slot-crossings in the improved ribbon screw feeder, can achieve a Bjerknes resonator action, with synergistic advantages to the usual continuous series of tuned resonant cavities at the refiner plate bar-crossings, at a frequency of half or integral multiples of the frequency of the helical ribbon bar/skewed axial slot-crossings, which can be adjusted to a family of resonant harmonic vibrations ranging from about 800 hertz to about 30,000 hertz.

MERCHANT's ORTHOGONAL CUTTING MODEL

The usual wood chip refining concept in rotating disc wood chip refiner apparatus is a beating and shearing action at refiner bar-crossings, similar to Merchant's orthogonal cutting model (18) which utilizes shear strength, density, friction, and percent of lignin as basic criteria. A steam pressure/temperature pre-treatment of most species of softwood and hardwood chips seem to provide a common shear strength/cutting force baseline, see Figure 8, so that usual rotating disc wood chip refiners can be utilized in mill operations with some loss of refiner capacity.

A steam pressure/temperature pre-treatment (say 15 minutes) is reported to be most practical for hardwoods like aspen and birch, but chemical pre-treatments are usual for eucalyptus, to provide water penetration into the hollow wood fibers to soften the lignin, to facilitate wood fiber separation and defibrillation by water flashing into steam and bursting the wood fiber, with the pressure/vacuum cycles at the bar-crossing flow regime.

Figure 8 appears to indicate that the steam pressure/ temperature pre-treatment of softwoods and hardwoods could be related to the quoteint of percent of lignin times shear strength, or the quoteint of percent of lignin times density, and appears to provide a common shear strength/cutting force baseline.

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WOOD	WAVE VELOCITY TRANSVERSE Meters/sec	% LIGNIN X SHEAR	% LIGNIN X DENSITY	Pre-Treat TEMP 0^{o}C
FIR BALSAM	1053	297	6.6	110
ASPEN	1022	200	3.4	140
SPRUCE	1010	300	5.7	105
PINE	965	336	8.1	120
BIRCH	931	480	9.0	180
MAPLE	900	550	9.9	190
OAK	834	541	12.	200

TABLE 1 Pre-Treat TEMPERATURE of SOFTWOODS and HARDWOODS FOR WATER PENETRATION to SOFTEN LIGNIN

CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. a helical ribbon screw feeder for a rotating disc wood chip refiner apparatus, said apparatus including a frame, parallel circular discs having facing surfaces and mounted concentrically on said frame, means for rotating at least one of the said discs and the said helical ribbon screw feeder, having a direction of rotation for relative counter-movement of said discs to each other; each said disc having a multiplicity of refiner plates with radial bars and slots, forming a continuous series of tuned resonant cavities in a multiple radial bar/slot-crossing flow regime; said helical ribbon screw feeder being adapted to feed wood chips to said refiner plates; including helical ribbon bars mounted on said helical ribbon screw feeder/rotating disc shaft by support lugs with bearings, a feeder outlet ring having an inner grid of skewed axial bars and slots, the said skewed axial slots are uniformly skewed and spaced circumferentialy inside the said feeder outlet ring in variable increments of volume; said increments forming an additional continuous series of tuned resonant cavities in a multiple helical ribbon bar/skewed axial slot-crossing flow regime. Each said helical ribbon bar having a leading edge in the direction of said rotation, a substantially horizontal top surface and two substantially vertical side surfaces; each said skewed axial bar having a leading edge in the direction opposite to the direction of said rotation; a substantially horizontal top surface and two substantially vertical side surfaces.

each said skewed axial slot having a substantially horizontal bottom surface between substantially vertical sides of adjacent said skewed axial bars inside the said feeder outlet ring, utilizing a family of resonant harmonic vibrations produced by self-sustaining oscillations of flow past cavities. The said skewed axial slots and bars in the said feeder outlet ring, as viewed from the said rotating means end, are uniformly skewed with an angle counter-clockwise for the said right-hand screw/ feeder outlet ring, and with an angle clockwise for the said left-hand screw/feeder outlet ring, so that the said helical ribbon bar/skewed axial slot crossings are nearly parallel, to suit commercial said helical ribbon screws with variable pitch to diameter ratios, and variable number of said helical ribbon bars on one said feeder shaft; and having a wave packet of forward travelling waves produced by the said additional continuous series of tuned resonant cavities at the said helical ribbon bar/skewed axial slot-crossings, which can achieve a Bjerknes resonator action by parametric resonance, with synergistic advantages to the said usual continuous series of tuned resonant cavities at the said usual refiner plate bar-crossings, at a frequency of half or integral multiples of the frequency of the said wave packet of said forward travelling waves, and can be tuned to suit Merchant's orthogonal cutting model, utilizing minimum cutting force and input energy, related to the shear stength, density, friction and percent of lignin in softwoods, hardwoods and eucalyptus species, and can be tuned to cause repeated flexing of single hollow wood fiber as a

vibrating string, leading to defibrillation with unravelled, brushed fiber ends, producing higher pulp quality by providing increased surface properties for a stronger pulp and paper sheet, and provides a longer refining residence time,
CHARACTERIZED in that said skewed axial slots and bars in the said feeder outlet ring, as viewed from the said rotating means end, are uniformly skewed with an angle counter-clockwise for the said right-hand screw/feeder outlet ring, and with an angle clockwise for the said left-hand screw/feeder outlet ring, so that the said helical ribbon bar/skewed axial slot-crossings are nearly parallel, to suit usual commercial said helical ribbon screws with variable pitch to diameter ratios, and variable number of said helical ribbon bars on one said feeder shaft.

2. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said feeder outlet ring is stationary, and the said helical ribbon bar is rotated by said means for rotating , each said helical ribbon bar having aleading edge in the direction of rotation, and each said skewed axial bar of the said feeder outlet ring having a leading edge in a direction opposite to the direction of said rotation of the said helical ribbon bar.

3. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said increments are such that the said skewed axial slot volumes between said skewed axial bars respond to said multiple helical ribbon bar/skewed axial bar-crossings at a resonant frequency ranging from about 800 hertz to about 30,000 hertz.

4. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said substantially horizontal top surface of said helical ribbon bar is sloped downward towards said leading edge of each said bar.

5. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said substantially vertical side surfaces of said helical ribbon bar are each sloped at an angle from the vertical such that each said bar is tapered down towards said top surface.

6. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said substantially horizontal top surface of said skewed axial bar is sloped downward towards said leading edge of said bar.

7. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said substantially vertical side surfaces of said skewed axial bar are each sloped at an angle from the vertical such that each said bar is tapered down towards said top surface.

8. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said substantially horizontal bottom surface of said skewed axial slot is sloped upwards from the horizontal at an angle in the direction of rotation.

9. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said leading edge of said helical ribbon bar is rounded.

10. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said leading edge of said skewed axial bar is rounded.

11. a helical ribbon screw feeder as claimed in claim 1, CHARCTERIZED in that said substantially horizontal top surface of said skewed axial bar is sloped downward towards said leading edge of said bar at an angle of about 6 degrees, said substantially vertical side surfaces of said bars are each sloped at an angle of about 6 degrees from the vertical such that said bar is tapered down towards said top surface, and said substantially horizontal bottom surface of said slots is sloped upwards from the horizontal at an angle of about 25 degrees in the direction of rotation.

12. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar-crossings can be tuned as resonant cavities discretely suited to the acoustic velocities of softwood, hardwood and eucalyptus species, thus promoting wood fiber separation and defibrillation in said wood chips.

13. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar-crossings can be tuned as resonant cavities discretely suited to the acoustic velocities of various sizes of wood chips, such as 3 mm(1/8 inch), 6 mm (1/4 inch), 9 mm (3/8 inch), thus promoting wood fiber separation and defibrillation in said wood chips.

14. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar/skewed axial slot-crossings cause repeated flexing of single hollow wood fibers as a vibrating string, leading to defibrillation with unravelled, brushed fiber ends, producing higher pulp quality by providing increased surface properties for a stronger pulp and paper sheet.

15. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar/skewed axial slot-crossings can be tuned to soften the discrete lignin contents of various softwood, hardwood and eucalyptus chips, thus promoting wood fiber separation and defibrillation, with a little damage to fiber surface properties.

16. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar/skewed axial slot-crossings have an operating environment which can be improved by increasing the pressure/ temperature of the steam atmosphere in the refiner and said wood chips, softening the lignin, promoting wood fiber separationn and defibrillation with less damage to said fiber surface properties.

17. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar/skewed axial slot-crossings initiates a family of tuned resonant harmonic vibrations by said self-sustaining oscillations of flow past said cavities, can achieve a Bjerknes resonator action by parametric resonance, with synergistic advantages to the usual said continuous series of tuned resonant

cavities at the said refiner plate bar-crossings, at a frequency of half or integral multiples of the said frequency of the said wave packet of said forward travelling waves, and provides a said longer refining residence time, and is conducive to more long-developed wood fibers.

18. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots at said helical ribbon bar/skewed axial slot crossings can be tuned to said Merchant's orthogonal cutting model, utilizing said minimum cutting force and input energy, related to said shear strength, density, friction, and percent lignin of said softwood, hardwood and eucalyptus species.

19. a helical ribbon screw feeder as claimed in claim 1, CHARACTERIZED in that said skewed axial slots and bars, as viewed from the said rotating means end, are uniformly skewed with a said angle from zero to 45 degrees counter-clockwise for the said right-hand screw/feeder outlet ring, and with a said angle from zero to 45 degrees clockwise for the said left-hand screw/feeder outlet ring, so that the said helical ribbon bar/skewed axial slot-crossings are nearly parallel, to suit commercial said helical ribbon screws with said pitch to diameter ratios of 0.2 to 1.5, and to suit 1 to 4 said helical ribbon bars located equally spaced radially on one said feeder shaft.

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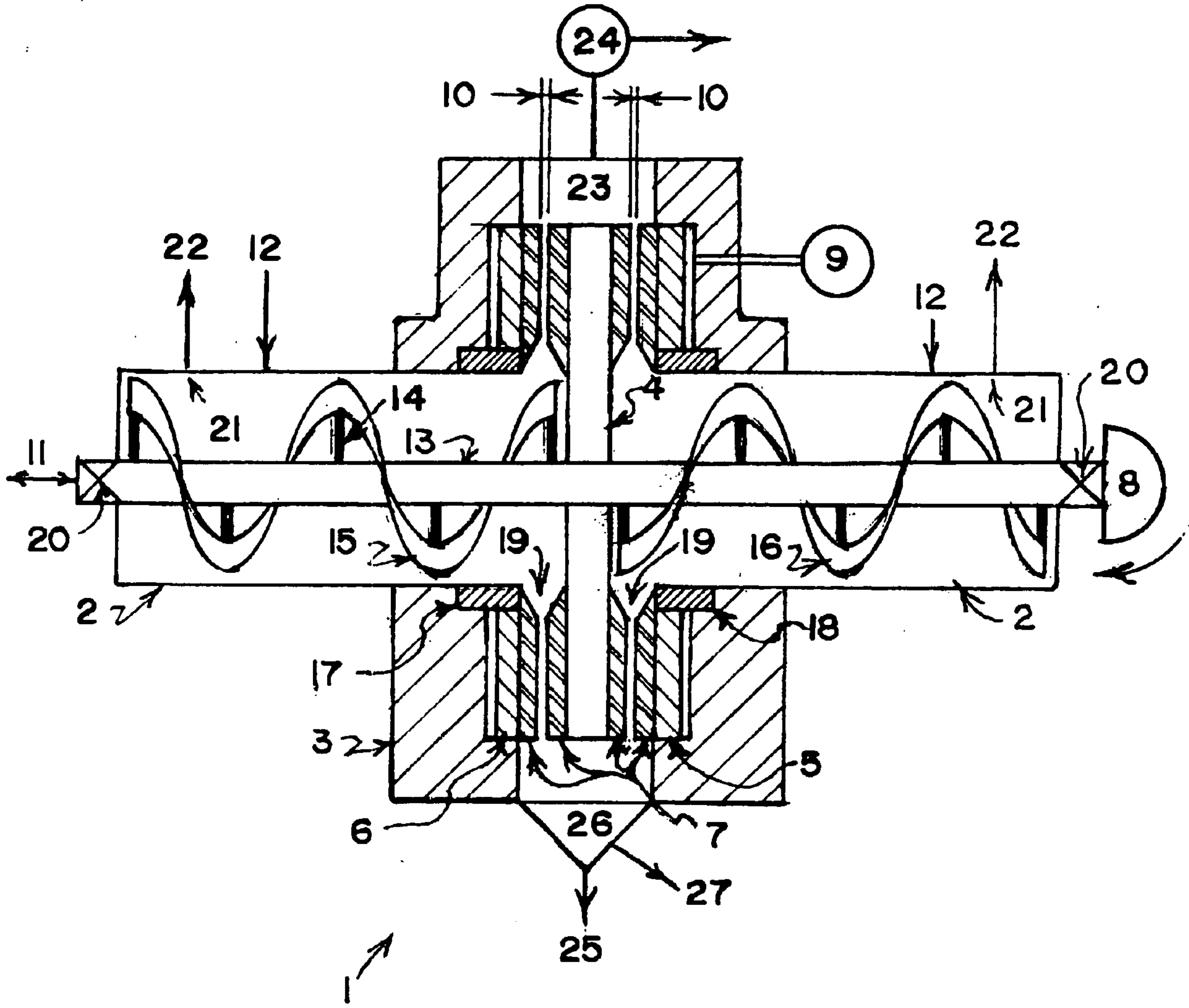
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FIG. 1

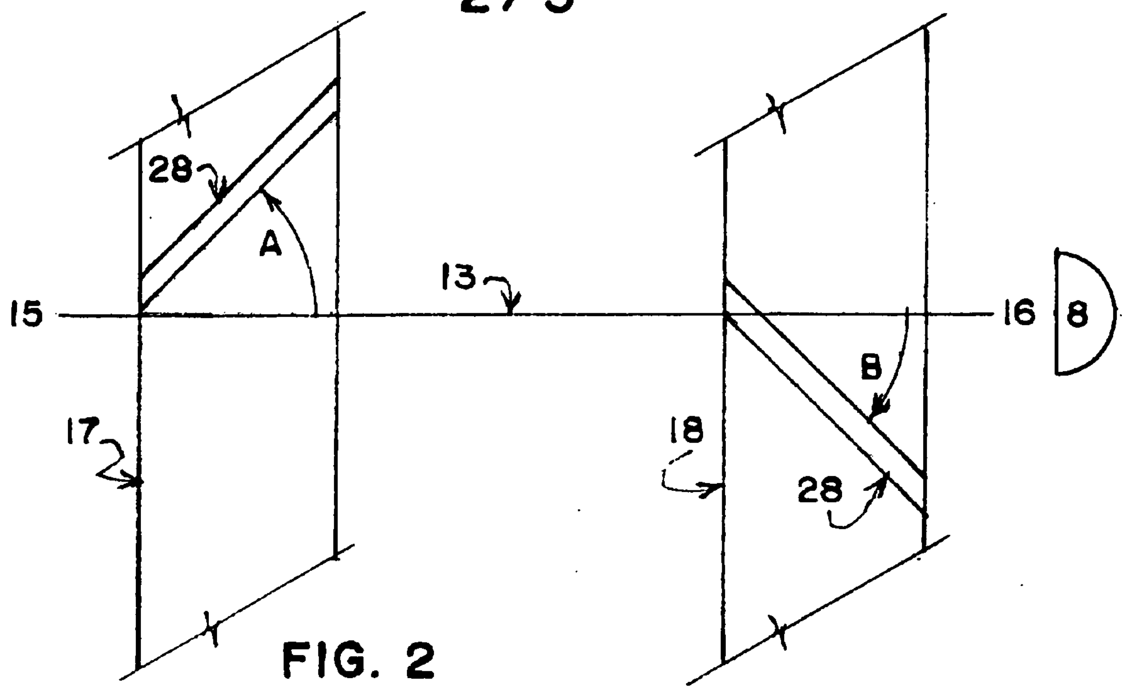

FIG. 2

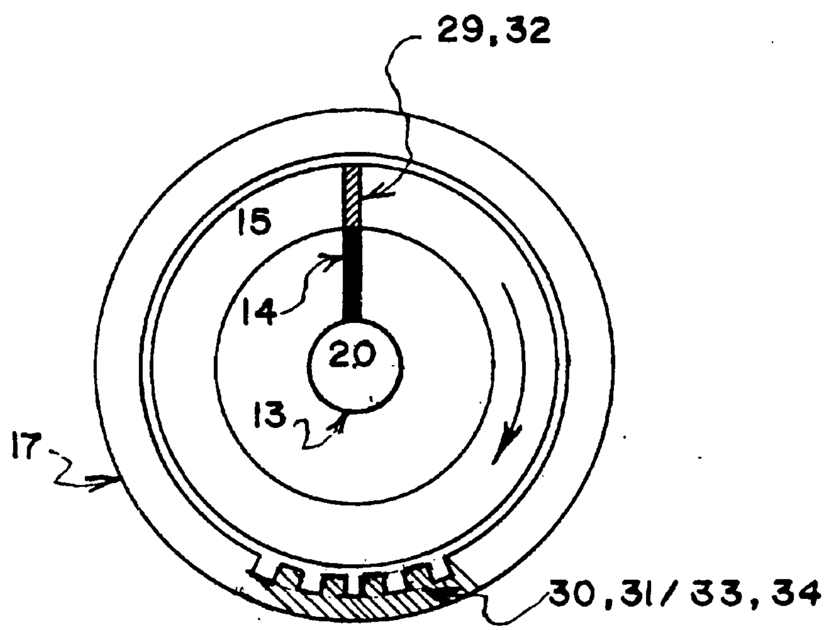

FIG. 3

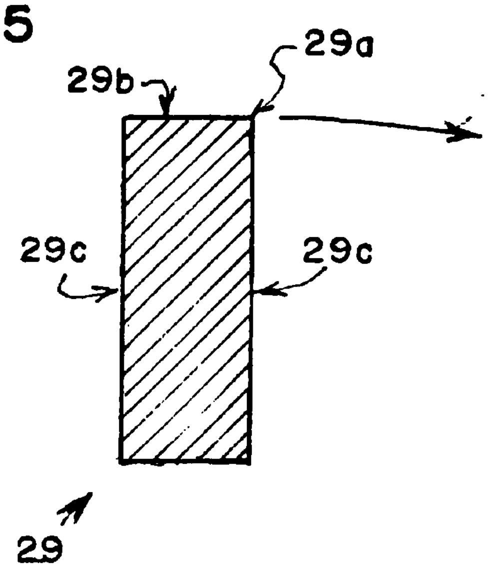

FIG. 4

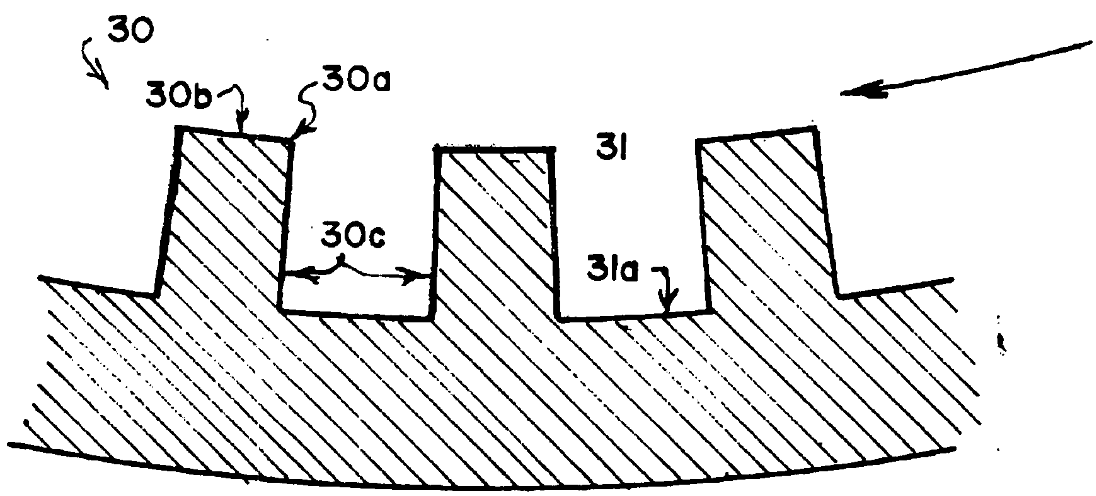

FIG. 5

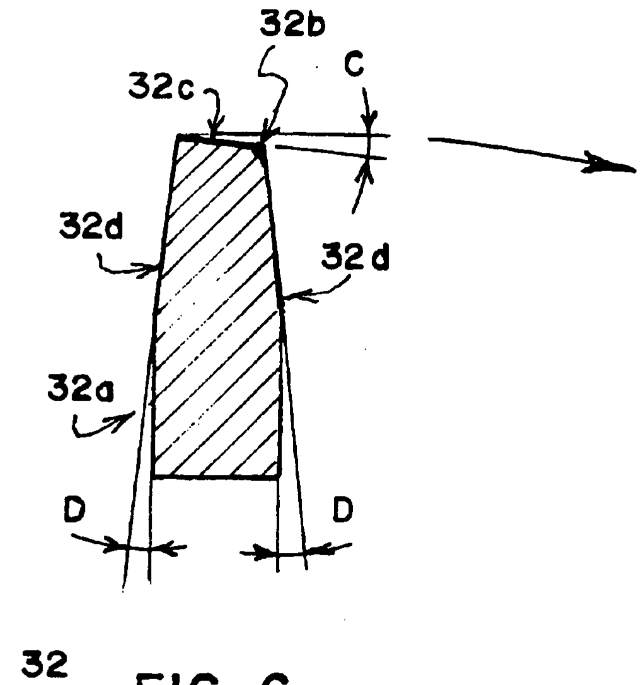

FIG. 6

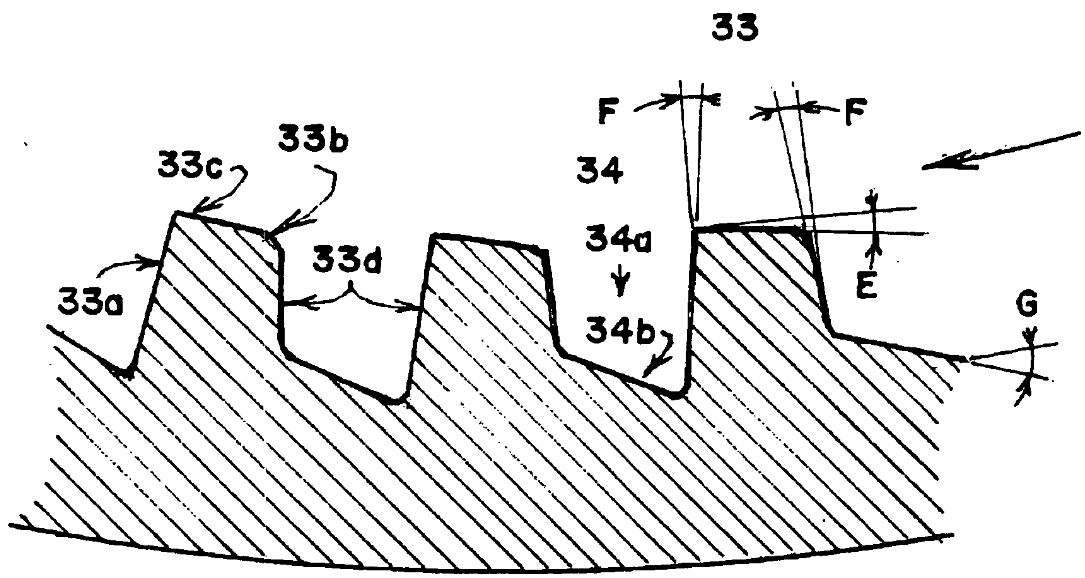

FIG. 7

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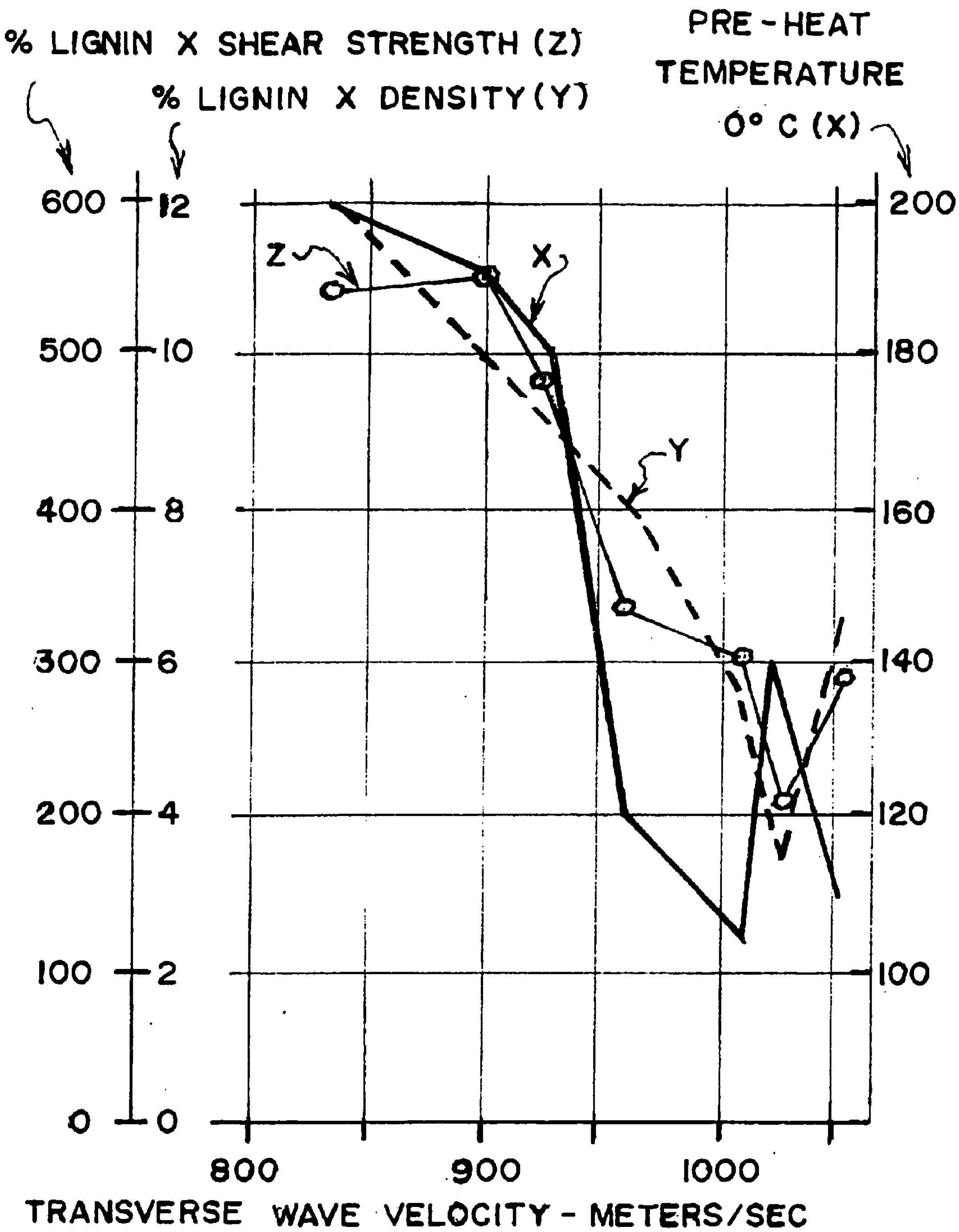
% LIGNIN X SHEAR STRENGTH (Z)
% LIGNIN X DENSITY (Y)
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600
500
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0
200
180
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140
120
100
Z
X
Y
800
900
1000
TRANSVERSE WAVE VELOCITY - METERS/SEC

FIG. 8